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The Disciplinary Nature of Science Teachers' Talk in the Process of Formative Assessment Design

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Abstract: Formative assessment is an important instructional practice in K-12 science classrooms and yet continues to be challenging for teachers to enact. Designing science-specific formative assessments requires teachers to leverage their understanding of science ideas, their understandings of how student understanding of content develops over time, and their understandings of pedagogical strategies that draw out student thinking. In this study, we analyze teacher conversations during the process of formative assessment co-design during a two-year professional development. We found heterogeneity in teachers' contributions both within and across meetings as teachers engaged in co-design. We document how the structure of the professional development process surfaced varied contributions on the part of the teachers, which led to the collaborative design and revision of a formative assessment task.

Introduction

There exists near-consensus in the science education community that formative assessment, or the practice of listening and attending to student ideas during the course of instruction, are essential elements of effective and equitable science learning & teaching (National Academies of Science, Engineering & Medicine [NASEM], 2018). Facilitating formative assessment successfully can be challenging for science teachers to implement (Sezen-Barrie & Kelly, 2017). It relies on science teachers having a repertoire of classroom practices that center student ideas and experiences alongside the science students are learning. Researchers have emphasized links between teachers' formative assessment practices and knowledge of how student ideas develop in a domain, or pedagogical content knowledge, in addition to their content knowledge of a discipline and general pedagogical knowledge of teaching strategies (Magnusson et al., 1999). However, how these different facets of "professional competence" (Blömeke et al., 2015) are represented within a professional learning community remains unexplored. In this paper, we investigate the distributed expertise of science teachers' knowledge base for formative assessment through an analysis of their conversations during a professional development on formative assessment task co-design.

Theoretical and conceptual framing

Teachers bring a wealth of experiences and resources to their learning (Putnam & Borko, 2000). As teachers make sense of new teaching practices, they draw on personal, social, and material resources to interpret these new practices and make necessary shifts to their instruction (Spillane et al., 2002). In professional learning settings, teachers' varied experiences across science teaching and learning become resources for the co-design of new instructional tasks and provide opportunities for learning (Penuel et al., 2007). This paper considers the ways in which the distributed expertise (Hutchins, 1995) of teachers in a professional learning community supported teacher development of formative assessment tasks. The cognition of groups is constructed through interactions between internal structures of individuals within the group and the structures external to the group that mediate their work (Hutchins, 1995). In the next sections, we describe the external structure of the formative assessment design cycle, which guided our approach to professional development, and the important internal cognitive resources that teachers may draw on within this cycle to co-design formative assessment tasks.

Formative assessment co-design as a site for teacher learning

While formative assessment tasks are often designed away from the school site by curriculum developers and measurement specialists (Bennett, 2011), the very teachers that enact them can contribute to their design (Ainsworth & Viegut, 2006). We have used co-design as an approach to develop common formative assessment tasks with teachers (Furtak, 2012). These tasks are common in that all teachers enact the same task in their classrooms, but they also create a common frame of reference in which to interpret student thinking. This supports teachers to clarify their own understanding of the content, clarify the goals for student learning, and forge professional consensus around the quality of teaching and student work (Danielson, 2007).

Our project followed an iterative, five-step professional development cycle called the Formative Assessment Design Cycle [FADC]. The purpose of this cycle was to situate teachers' work in their own classrooms and to draw upon their knowledge and experiences to develop, enact, and revise a set of common formative assessments (Furtak, 2012). In this cycle, teachers *Explore* student thinking in a domain, *Design* instructional tasks for drawing out student thinking, *Practice* using those tasks, *Enact* the tasks and collect evidence of student learning in the form of student work and video, and then *Reflect* upon that process of enactment and make necessary revisions to the formative assessment task.

Science teachers' personal resources for formative assessment task co-design

Teachers enacting formative assessment need to complement their deep knowledge of formative assessment strategies and domain-specific content with understanding of how students learn in a given domain, the common everyday experiences they are likely to leverage as they learn, and strategies for supporting students as they advance in their understandings (Bennett, 2011). Research on science teachers' formative assessment practices highlight key personal resources that they may draw on as they as work to collaboratively develop science-specific formative assessment tasks. These resources include their understanding of the science content (Forbes et al., 2015) and their beliefs about how students learn in science (Box et al., 2015). We add teachers' domain-general practices, such as stop lighting, which are common school-based formative assessment practices.

In this paper we consider how science teachers, with heterogeneous experiences relative to different science ideas, science teaching, and pedagogy in general, contribute to the process of co-design of a formative assessment task during a two-year professional development program. Specifically, we ask (1.) What personal resources did teachers draw on during the process of formative assessment co-design? (2.) How did the heterogeneity of teachers' contributions relate to the co-design of a formative assessment task?

Method

We explore data gathered in a two-year study in which a department of high school biology teachers collaborated with university researchers to co-design, enact, and revise a set of common formative assessment tasks about natural selection. The study was conducted for two years on-site with a team of biology teachers at large suburban high school of a large city in the western US. Seven teachers participated in the professional development meetings across the two years of the study with a range of teaching experience (3-29 years) and varied expertise in science.

Content and curriculum

The content focus of the professional development was evolution by the process of natural selection. Natural selection provides rich opportunities for teachers to explore the myriad ideas students have about how populations of organisms and individuals change over time (Anderson et al., 2002). At the beginning of the study, teachers did not plan together, and there were few activities shared among teachers and no common assessments.

Sources of data

Sources of data include videotapes made during each of the on-site professional development meetings, each about 60-90 minutes long, supplemented by field notes and drafts of the formative assessments. We trace the co-design of one common formative assessment task. Although teachers and researchers developed several formative assessments during the study, we chose to focus on the trajectory of a single assessment task, *Natural Selection vs. Individual Change* for two reasons. First, teachers were central in problematizing and developing this formative assessment. Second, teachers used artifacts of practice, in the form of written drafts of the assessment and videotapes of enactment, to reflect upon and revise the assessments for use in their classrooms during the project. We reviewed content logs and identified all instances of discussion around the task and created detailed transcripts. Overall, we sampled 125 minutes of videotape across 5 professional development sessions. The transcripts corresponded with video excerpts varying in length from 13 minutes to 34 minutes, with a mean length of 25 minutes and median length of 24 minutes.

Data analysis

We segmented transcripts of the videotaped meetings into speaking turns and gave each segment a set of tags for length and speaker. We developed a coding system to categorize talk turns as having a focus on disciplinary ideas, discussions specific to the teaching of those ideas (science teaching), or more general teaching topics (general pedagogy). Three of the authors independently coded all transcripts (disciplinary ideas: agreement=89%, r= 0.58, K=0.53; science teaching: r=0.43, K=0.38; teaching: r=0.62, K=0.59; transitions: r-0.31, K=0.23). We then discussed and adjudicated all disagreements.

Results

Our coding of the discussions reveals heterogeneous contributions to the conversation about task design. Figure 1 illustrates how each of the teachers and the facilitator (Carrie) had similar contributions in terms of the talk within the meetings, although their contributions were often in different domains, illustrating both the heterogeneity of teachers' contributions and their own experiences in science and teaching. Furthermore, the emphasis on working out the details of the disciplinary ideas around natural selection was reflected in the contributions of each of these participants during the design phase, and then equally transitioned to discussions focused on science teaching during the reflect and revise phases of the study.

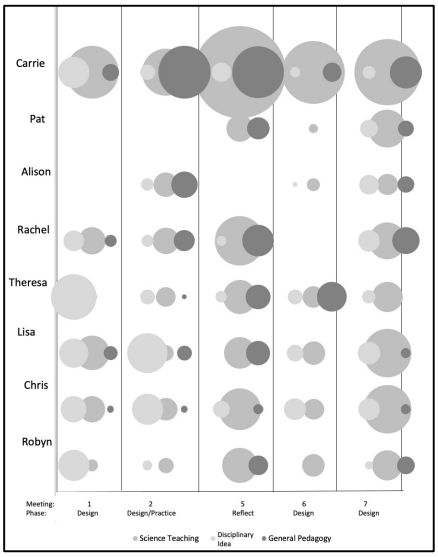

Figure 1. Bubble plot of relative proportion of teacher utterances.

Distribution of talk across the FADC

We next investigated the ways in which the types of talk and teacher contributions were distributed across co-design activities in different meetings. We mapped the distribution of the three types of talk segments across time for each of the meetings, which revealed differences in teacher talk between meetings focused on Design and Reflection (which includes revision of the task). When teachers talked about designing the task, they engaged in sustained conversations about disciplinary ideas, interspersed with conversations about science teaching, which involved turning those science examples into a formative assessment designed to get at student thinking about phenotypic variation and whether it was a result of natural selection or individual change. For example, in the following segment the teachers were working out an example for the task that asked students if rabbits' fur changing color in different seasons was an example of individual change or natural selection. Chris initiated a conversation about the science behind the example:

Chris:	Does anybody know about the rabbit, what if a rabbit had a baby in the winter?
Theresa:	But they are always born in the spring. [Laughter] Because they are hibernating in the winter.
Chris:	What if they had a baby in the spring and then you took the baby and put it in snow.
Alison:	In an environment, so you took it -
Chris:	Yeah, if you took out of the in the summer and stuck it in the freezer would it turn.
Rachel:	I believe you couldn't because there have been experiments you put ice packs on them.
Theresa:	Oh yeah, I've seen that.
Rachel:	It's an enzyme, it's a cold
Lisa:	That's one of the ones in the scientific method [referring to the textbook]
Chris:	I didn't know that.
Theresa:	Don't put the bunnies in the freezer [Laughter]

In conversations such as these, the teachers drew on each other's knowledge of the process of natural selection to better work out the mechanisms of change in the specific example of the arctic hare. While most of the talk in developing the assessment focused on disciplinary ideas during the reflection phase, teachers' conversations shifted to a focus on general pedagogical strategies and science teaching, with interspersed discussions on the science content as the assessment was revised. During meetings in these later phases of the design process, teachers watched a video of Theresa leading her class in a discussion around the examples and engaged in conversations about general pedagogy and science teaching early in the meeting, stimulated by the video, which then led into a sustained conversation later focused on a possible revision of the task. There are only a few talk turns dedicated to disciplinary ideas exclusively. Throughout these conversations, we observed teachers' different

contributions to discussions as they raised questions about the nature of different aspects of natural selection, the ways it was represented in the task, and how they would lead the task with students.

Discussion

The analysis described in this paper provides evidence that the heterogeneity of the contributions by the group during the process of formative assessment task co-design provided opportunities for teacher learning about disciplinary ideas and practices, the students they teach, and pedagogy in general. Rather than looking at the knowledge within teachers' own minds, we explore how their contributions can productively contribute to the design of a task. In this way, we shift the focus from the knowledge teachers need to enact a task, to the ways in which their varied expertise in science and in schools contributes to formative assessment design. The majority of the changes to the formative assessment grew directly from teachers' conversations about science content, as well as student ideas and instructional approaches to teaching that content. Research models, such as research + practice partnerships (Coburn & Penuel, 2016) that include various stakeholders can further support these learning opportunities for teachers as they engage with various forms of expertise in the co-design process.

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